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मानक

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Mazdoor Kisan Shakti Sangathan

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Jawaharlal Nehru

“Step Out From the Old to the New”

IS 7500 (2000): Code of Practice for Installation and Observation of Cross Arms for Measurement of Internal Vertical Movement in Earth Dams [WRD 16: Hydraulic Structures Instrumentation]



“ज्ञान से एक नये भारत का निर्माण”

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“ज्ञान एक ऐसा खजाना है जो कभी चुराया नहीं जा सकता है”

Bhartrhari—Nitiśatakam

“Knowledge is such a treasure which cannot be stolen”

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भारतीय मानक

मिट्टी के बाँधों में आंतरिक ऊर्ध्वाधर संचलन के मापने के लिए
क्रास आर्म के स्थापन और निरीक्षण की रीति संहिता
(पहला पुनरीक्षण)

Indian Standard

CODE OF PRACTICE FOR INSTALLATION AND
OBSERVATION OF CROSS ARMS FOR MEASUREMENT
OF INTERNAL VERTICAL MOVEMENT IN EARTH DAMS
(*First Revision*)

ICS 93.160;17.020

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BUREAU OF INDIAN STANDARDS
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NEW DELHI 110002

FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Hydraulic Structures Instrumentation Sectional Committee had been approved by the Water Resources Division Council.

Generally the more important field observations made on the behaviour of earth dams are those of settlement of embankment and measurements of internal pore pressure. These provide a record of field performance and furnish information that would enable future designs to be based on realistic conditions. Vertical movement devices provide a means of determining volume change within the embankment and settlement of foundations, and identify zones of excessive and uneven settlement which may lead to stability problem and cracking. The cross arm installation especially permits the measurement of consolidation within any desired lift or lifts of embankment both during and after construction. Consideration governing the choice and location of this instrument is given in IS 7436 (Part 1) : 1993 'Guide for types of measurements for structures in river valley projects and criteria for choice and location of measuring instruments : Part 1 For earth and rock-fill dams'.

This standard was first published in 1974. A revision of this standard has been taken up to incorporate certain changes found necessary in the standard in the light of comments received from the users. The major changes in this revision are inclusion of paragraphs on general guidance, maintenance and advantages and limitations of the mechanical type of installation. However, these provisions for electrical type of installation shall be considered for inclusion as soon as text for the same is prepared and finalized.

In the formulation of this standard due weightage has been given to international co-ordination among the standards and practices prevailing in different countries in addition to relating it to the practices in the field in this country. As per USBR Publication 'Embankment Dam Instrumentation Manual, Jan 1987', mechanical type of cross arms is not being used in that country because other instruments that are easier to install and monitor have been developed.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (revised)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

CODE OF PRACTICE FOR INSTALLATION AND OBSERVATION OF CROSS ARMS FOR MEASUREMENT OF INTERNAL VERTICAL MOVEMENT IN EARTH DAMS

(First Revision)

1 SCOPE

This standard covers the requirements of installation and observation of cross arms of the mechanical and electrical types of measurement of internal vertical movement of earth dams. Vibrating wire settlement sensor which are being increasingly used now has not been covered here.

SECTION 1 MECHANICAL TYPE

2 REFERENCE

The following standard contains provision which through reference in this text, constitutes provision of this standard. At the time of publication the edition indicated was valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent edition of the standard indicated below:

IS No.	Title
6935 : 1973	Method for determination of water level in a bore hole

3 EQUIPMENT

3.1 Components of Installation

3.1.1 Base Extension

The base pipe extension consist of two lengths of 50 mm nominal bore steel pipe for extending 2 350 mm below the middle of the bottom cross arm placed on the foundation excavation line. The lower 600 mm length of 50 mm pipe in the foundation serves as a trap to catch debris and is separated from the upper 1 500 mm length by latching plate. The base extension anchors the installation to the foundation and provides room to latch the pawls on the measuring device (see Fig. 1).

3.1.2 Cross Arm Unit

The cross arm unit is a 1 000 mm length of 40 mm nominal bore steel pipe to which a 1 000 mm length

of 75 mm steel channel (6.8 kg/m) is fastened with a U-Bolt normal to the pipe length at the centre point. The cross arm anchors the column of telescoping pipe to the embankment (see Fig. 1).

3.1.3 Spacer Section

This section is a length of 50 mm nominal steel pipe that serves as a spacer between the cross arm units. It is 2 500 mm long for the 3 000 mm spacing of cross arm units (see Fig. 1) in rock-free soils. The spacer pipes are cut to two 1 250 mm length and connected by pipe couplings when the units are installed in rocky soils.

NOTE — When the measurements of vertical movement is desired at intervals of 1 500 mm the cross arm units will be placed 1 500 mm centre to centre, and the length of the spacer section will be 1 000 mm.

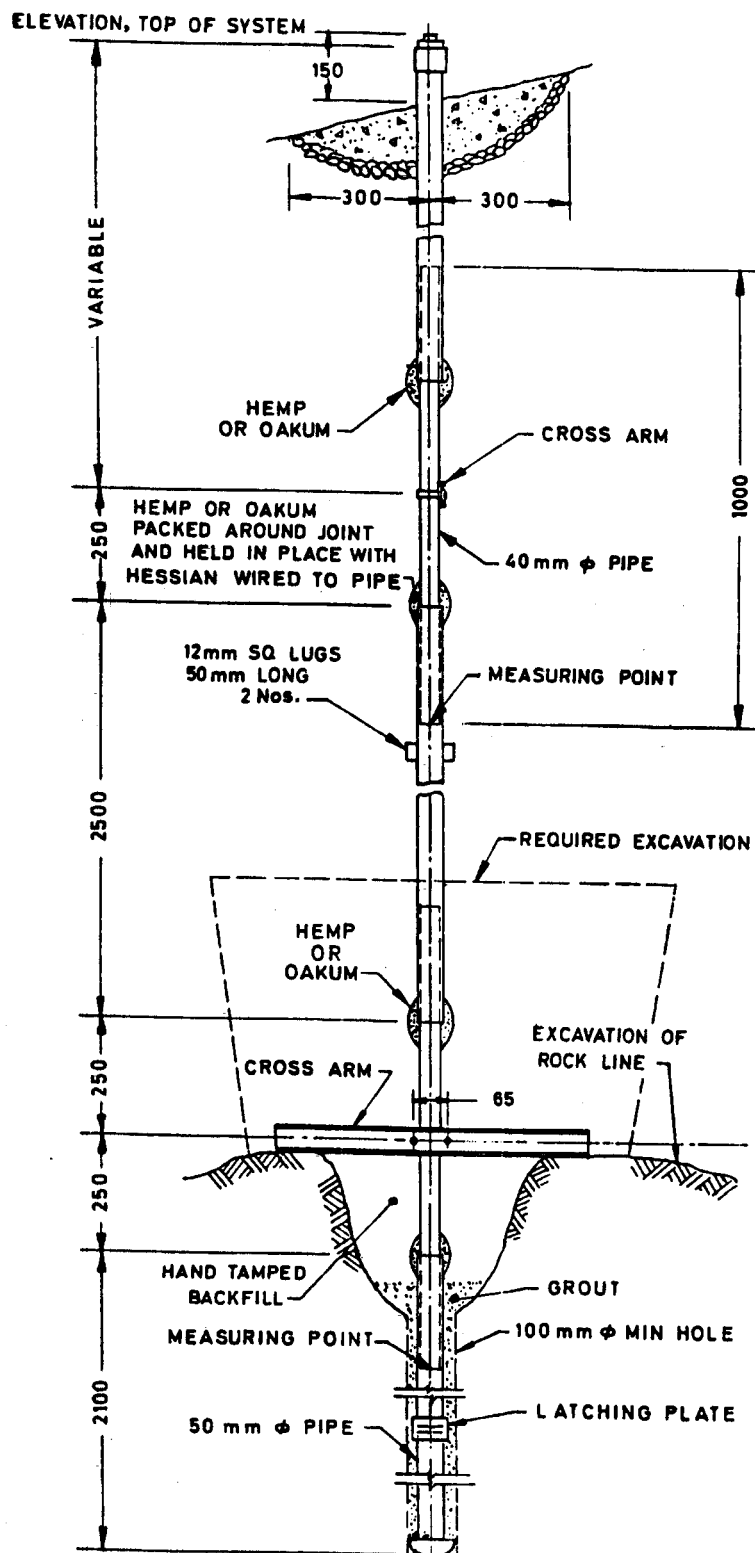
3.1.4 Top Section

This piece of 50 mm nominal bore steel pipe of variable length extends the column of pipe to the surface of the embankment. It is capped by a 50 mm coupling and a pipe plug. The reading scale is attached to this top section while readings are taken. When the installation is completed, the top section should be encased in concrete to reduce horizontal displacement. An 'asbuilt' elevation to the nearest 2 mm should be established for the pipe coupling on the top of the pipe (see Fig. 2).

3.2 Equipment for Observation

3.2.1 Measuring Torpedo

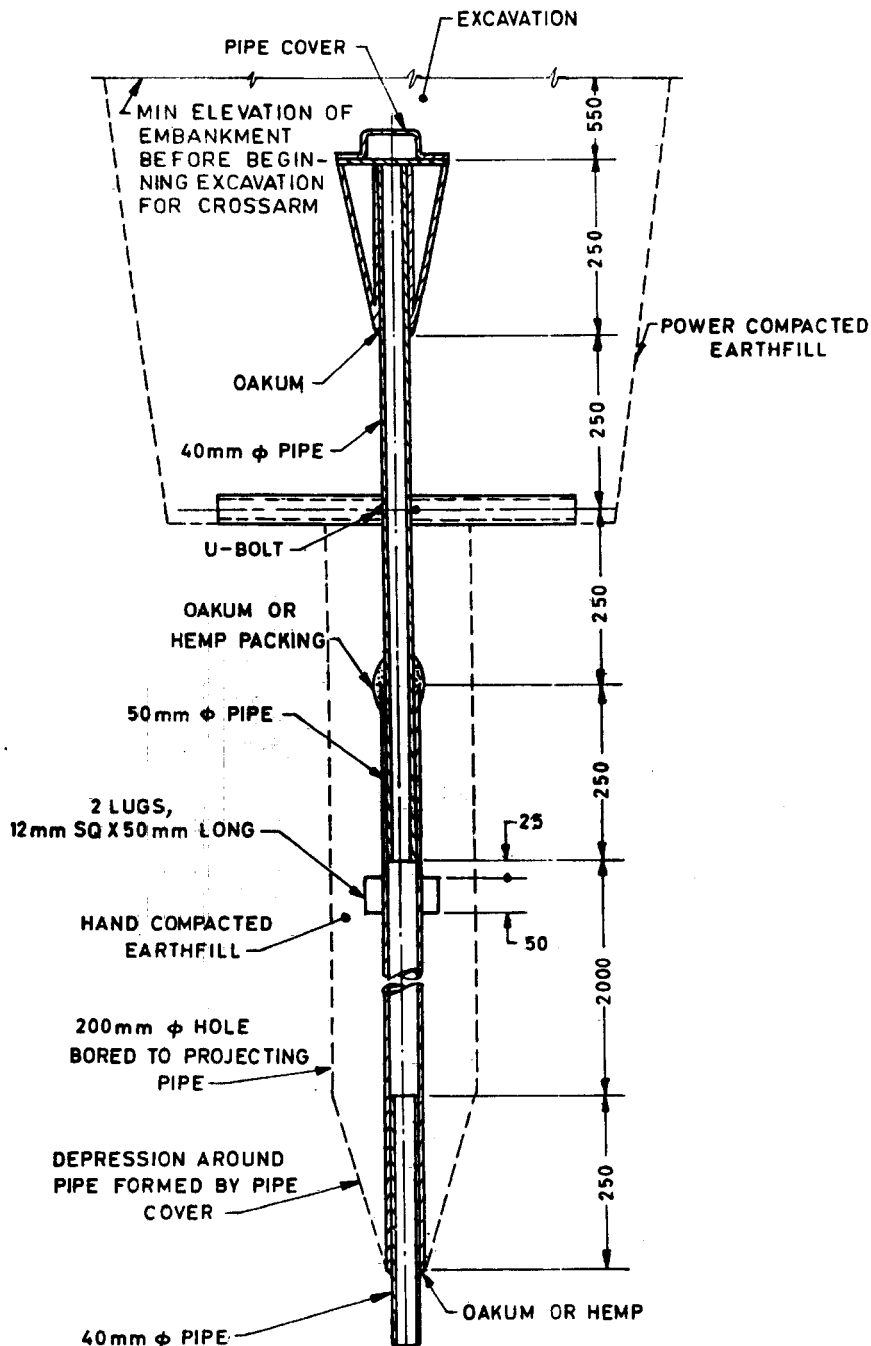
Readings of cross arms are taken by lowering from the top of the cross arm system, a torpedo attached to a steel measuring tape or calibrated stainless steel aircraft cable. The torpedo is machined to dimensions from a brass shaft and contains two wings or pawls which open or close at opening and closing slots due to spring action. The maximum dimension of torpedo at the wings when fully opened is less than 50 mm and greater than 40 mm (see Fig. 3).



NOTE — As each cross arm unit is placed, determine the elevations of all cross arms installed.

All dimensions in millimetres.

FIG. 1 TYPICAL INSTALLATION OF CROSS ARM, MECHANICAL TYPE FOR 3 000 mm SPACING — GENERAL.



All dimensions in millimetres.

FIG. 2 TYPICAL INSTALLATION OF CROSS ARM, MECHANICAL TYPE FOR 3 000 mm SPACING—DETAIL NEAR TOP

3.2.2 Reading Scale and Adaptor

The details of reading scale with adaptor used for lowering the torpedo are given in Fig. 4. If torpedo is attached to calibrated stainless steel aircraft cable, reading scale may be suitably modified for aircraft cable.

3.2.3 Water Level Indicator

Any suitable device as described in IS 6935. The measuring devices should be kept clean and free of grit. It is suggested that each type of instrument be disassembled, in so far as practicable, and cleaned following completion of readings. The tape should be carefully inspected for kinks and breaks.

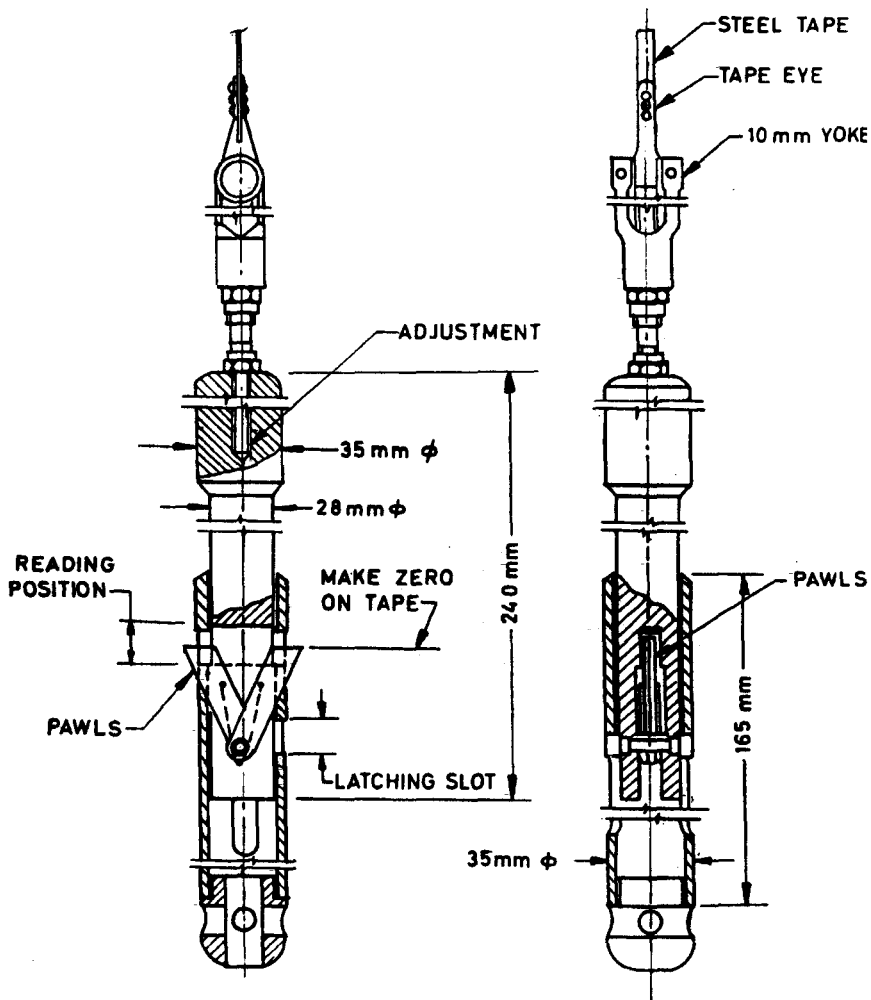


FIG. 3 MEASURING TORPEDO

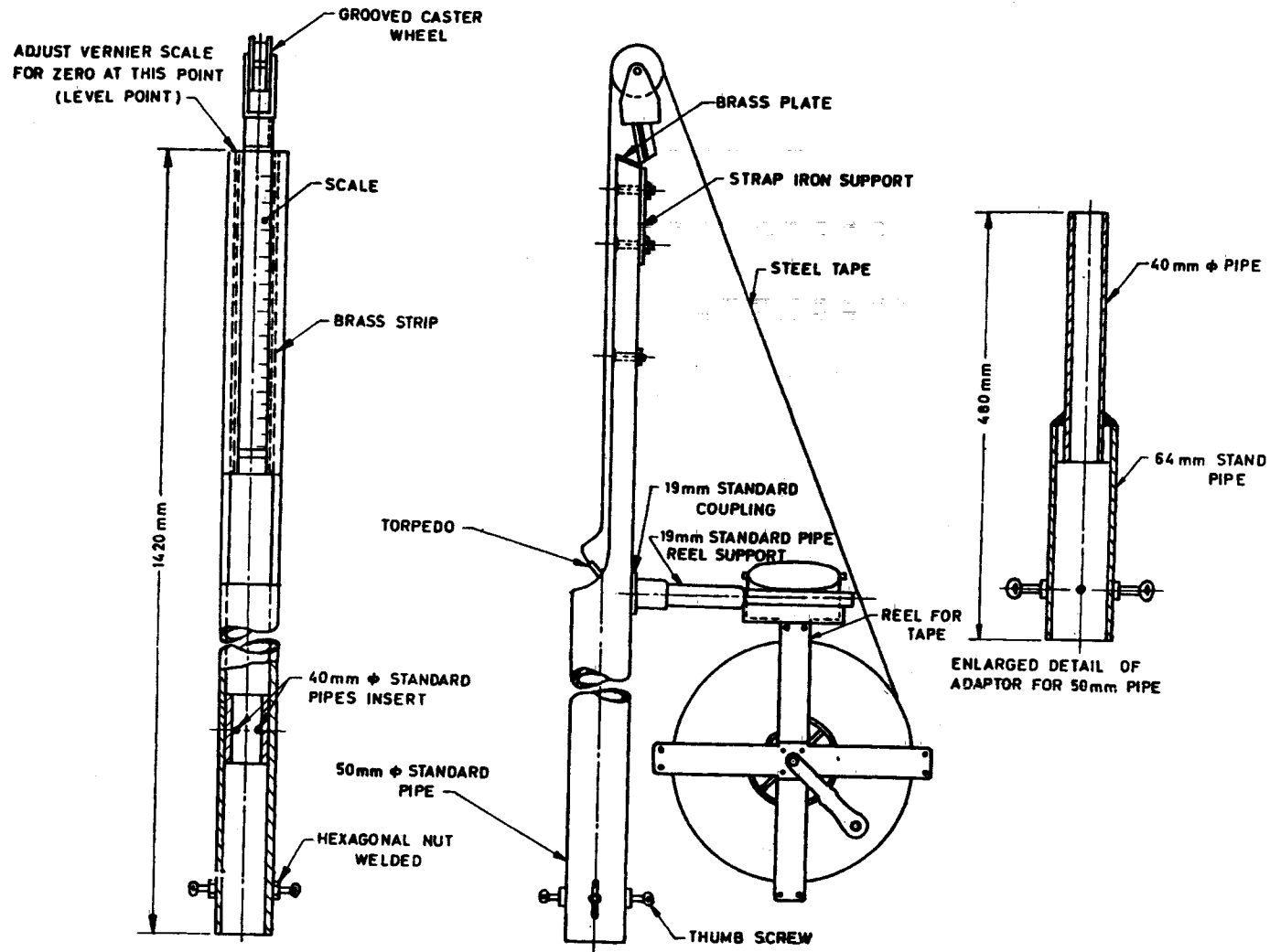
4 METHOD OF LOCATING A COLUMN OF CROSS ARMS

Prior to installation of the test equipment, permanent instrument benchmarks and targets should be established on the abutments of the dam. These targets should be visible and accessible throughout construction of the entire embankment. From the control targets of especially established targets on opposite abutments, line can be extended which will pass over and will intersect at the centre of the installation. From this system of intersecting baselines, temporary straddle hubs may be established at any embankment elevation. When chalk lines are stretched between the straddle hubs, the points of intersection will be the centre of the installation.

5 DESCRIPTION OF INSTALLATION

The installation comprises a series of alternate telescopic 40 mm diameter and 50 mm diameter pipe

sections anchored to the embankment by horizontal cross arms. The base extension is installed at the foundation level while the cross arm and spacer sections are placed alternatively, one above the other up to the top of the dam progressively as the construction proceeds. To prevent the ingress of soil all telescopic joints should be protected with oakum or hemp packing held in-place by hessian wired on to the pipes. The cross arms are installed progressively as the embankment is placed. Settlement readings are obtained by means of the specially designed measuring torpedo. The torpedo is lowered into the pipe barrel by means of a steel tape of the cable so attached that the upper edge of the pawls of the torpedo corresponds to zero points of graduation of the tape or the cable. While making a measurement the torpedo is lowered to a point a few centimetres below the elevation of the uppermost measuring point, then lifted until the extended pawls engage the lower end of the inside 40 mm diameter pipe.



NOTES

- 1 Recommend a 15-kg spring scale, grapple hook, tape clamp handle and a 10-kg tension on tape when taking settlement readings.
- 2 Use device as shown during construction. Thereafter cut device to 1200 mm length and thread bottom end of 50-mm pipe to fit top of installation.

FIG. 4 READING SCALE WITH ADAPTOR

6 INSTALLATION

6.1 The vertical movement apparatus should be installed as embankment placement operations progress. Each pipe section should be placed in a vertical position. The operation of all heavy equipment should be prohibited in the immediate vicinity of the installations when sections of the apparatus are being placed. If, for some reason, the upper surface of the embankment in the vicinity of the installation should be reworked before an additional unit is completed, the installation should be flagged or prominently marked so that it will not be damaged or displaced by earth moving equipment (*see* Fig. 1).

6.2 Base Extension

The base extension for the device consists of two pieces of the pipe which form the extension into the foundation. This extension is assembled and set into a 10 mm minimum diameter hole which has been drilled to the required depth into the foundation. The hole may be drilled by wash boring, churn drill, earth auger or diamond drill depending upon the type of foundation material and equipment available. After setting the pipe extension, the backfill around the 50-mm pipe should be done with cement grout to within 250 mm of its top. If the foundation cross arm is not installed immediately, a temporary pipe cover should be placed over the extending 50-mm pipe and covered with a 450 mm minimum of compacted embankment material.

6.3 Placing Cross Arm Units

The vertical movement apparatus (*see* Fig. 2) can be installed either in 'rock-free' soil or in 'rocky' soils or in a combination of soil as found in a zoned type of earth and rockfill embankment. A 'rock-free' soil is defined as a soil that can be penetrated by 250 mm diameter power auger. Installation of the apparatus in 'rock-free' soils is given in 6.3.1 and in 'rocky' soils in 6.3.2.

6.3.1 Procedure for Installation in Rock-Free Soils

6.3.1.1 In 'rock-free' soils the embankment should reach an elevation of approximately 4 500 mm above the measuring point of a cross arm unit previously placed before excavating the trench for the next cross arm. After excavating the bench and boring the hole for a cross arm unit, a section of lightweight pipe or tubing may be placed in the hole to keep dirt from entering the pipe system when the pipe cover is removed from the existing installation. The pipe cover should be removed and replaced as required with twisting motion in order to retain undisturbed, the

hemp or oakum packing between the lengths of telescoping pipe.

6.3.1.2 A practical method for boring the required holes below the excavated trench for a cross arm unit is by the use of a power auger. After the cross arm unit is installed, the angular space surrounding the pipe in the bore hole should be backfilled with selected fine material and the soil compacted by hand rodding around the telescopic pipe section.

6.3.1.3 Because of the difficulty in working the bottom end of the 2 500 mm length of 50 mm spacer pipe over the projecting 40 mm pipe from the underlying cross arm unit, lugs are welded to opposite sides of the 50 mm pipe at about 300 mm from its top. A special tee wrench may be fabricated on the job to slip over the top end of the 50 mm pipe engaging the lugs, and permitting the 50 mm pipe to be twisted and worked down over the 40 mm pipe for the required 250 mm. The engaging end of the wrench consists of 400 mm length of 65 mm nominal bore pipe, having two 15 mm wide slots, 75 mm deep. To this piece of 65 mm pipe, two pieces of 25 mm nominal bore, steel pipe, approximately 900 mm and 1 200 mm long respectively, are welded to form a T-shaped handle. The 250 mm of overlap of the 50 mm spacer pipe over the projecting 40 mm pipe, deep in the augered hole, can be determined by lowering a T-shaped stick which has been notched at a length of 2 250 mm, inside the 50 mm pipe.

6.3.1.4 When the embankment contains a considerable amount of rock, the augering of hole for installation of cross arm units can be expedited if the backfill over the pipe cover is selected fine material. This fine material can be placed and compacted inside a cylinder of metal pipe or tubing having an internal diameter of approximately 250 mm. The pipe may be progressively jacked to a higher elevation. When the hole is augered for succeeding cross arm unit, most of the fine material is removed.

6.3.1.5 Backfilling trenches for cross arm unit

When the trench has been backfilled with typical embankment materials to within approximately 300 mm of the top of the 40 mm pipe (bottom of pipe cover) the initial elevation of the cross arm measuring point should be recorded as described in 7.2.1. Thereafter, a minimum of 500 mm of typical embankment material should be compacted over the pipe cover before embankment placing operations are resumed at the place of installation.

6.3.1.6 The sequence of operations involved in installation of cross arm device in rock-free soils is given in Fig. 5.

6.3.2 Procedure for Installation in Rocky Soils

6.3.2.1 Since boring of holes for aligning the cross arm device is not possible in rocky soils, a practicable method is mounding around the 40 mm pipe of the cross arm device. This method should be adopted in previous zones of zoned embankments.

6.3.2.2 The cross arm device should be placed and then aligned and backfilled with previous (rocky) material up to 250 mm above the cross arm. The lower 1 250 mm section of 50 mm spacer pipe should then be placed and aligned.

6.3.2.3 The pipe cover should be placed and rocky materials mounded to lower end of pipe cover. The embankment should be raised 1 200 mm above cross arm. The upper 1 250 mm section of 50 mm spacer pipe with coupling should be connected to the lower section of the spacer pipe and pipe cover should be put on the top of the upper section of the spacer pipe.

6.3.2.4 Rocky material should be mounded around the upper section of spacer pipe. Embankment placing should be continued to 150 mm above top of pipe

cover leaving a depression around the pipe cover. A 50 mm thick sand pad should be placed and then the cross arm device should be placed and aligned (after removing the top cover of the upper spacer pipe).

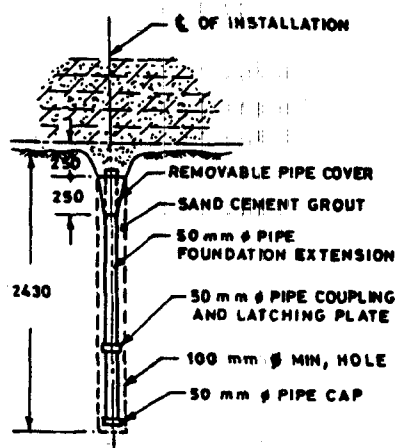
6.3.2.5 The sequence of operations involved in installing cross arms in rocky soils is given in Fig. 6.

6.4 Correction for Alignment

After installing the 2 500 mm length of spacer pipe in the bored hole and again after the cross arm assembly has been installed, the protective pipe cover should be removed and the vertical alignment of the system checked by lowering a plumb bob from the straddle hub strings. If it is impracticable to correct the error, succeeding pipe sections should be placed vertically and the offset from the true vertical alignment recorded. If a deviation from vertical alignment is found, an attempt should be made immediately to correct the error.

6.5 Rotation of Cross Arms

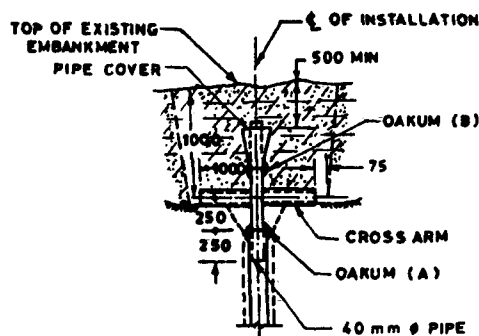
Each cross arm section should be placed in a manner that will distribute the weight of the channel



PHASE 1

Operations

1. Locate centre of installation
2. Level 90 cm dia area adjacent to centre of boring
3. Bore 100 mm minimum dia hole; clean hole
4. Place and align foundation extension in hole
5. Place sand-cement grout around pipe preferably with a tremie
6. Place removable pipe cover; tamp fine soil around cover to foundation line
7. Compact embankment above installation



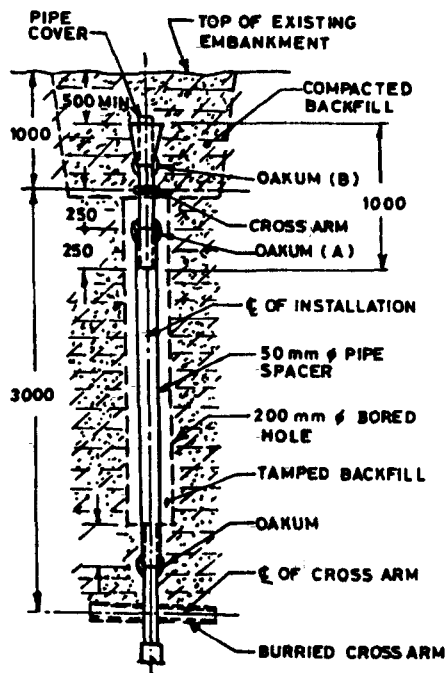
PHASE 2

Operations

1. Locate centre of installation
2. Excavate trench remove soil above soil pipe cover
3. Remove pipe cover from foundation extension
4. Place and align cross arm
5. Place pipe cover at top of 40 mm pipe, warp with oakum burlap of (A) and (B)
6. Backfill hole and trench to level of oakum (B)
7. Obtain original elevation of cross arm measuring point
8. Complete backfilling
9. Continue embankment placing

All dimensions in millimetres.

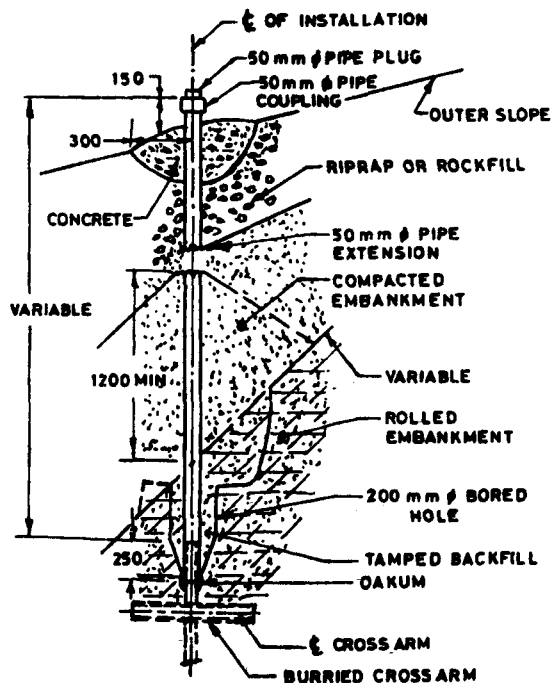
FIG. 5 TYPICAL VERTICAL MOVEMENT DEVICE — INSTALLATION IN ROCK-FREE SOILS (Continued)



PHASE 3

Operations

1. Locate centre of installation
2. Excavate trench
3. Bore hole, remove pipe cover
4. Place 50 mm spacer pipe, align pipe
5. Backfill hole to 400 mm below bottom of trench
6. Continue with operation 4 through 9 of phase 2
7. Repeat operation for each cross arm unit



PHASE 4

Operations

1. At outer slope of rock-free zone locate centre of installation
2. Level a working area, bore hole
3. Assemble, place and align 50 mm standard pipe extension to outer surface of embankment
4. Backfill hole
5. Mould rocky soils around pipe to outer embankment slope
6. Place concrete

All dimensions in millimetres.

FIG. 5 TYPICAL VERTICAL MOVEMENT DEVICE — INSTALLATION IN ROCK-FREE SOILS

section and prevent misalignment of the vertical column of pipe. When each new cross arm unit is installed, the channel section of the new unit should be rotated 90° (clockwise) with respect to the channel section previously placed.

6.6 Compaction of Soil Around Installation

Soil around the installation should be compacted to the equivalent unit dry weight of the surrounding material and recorded samples of the soil at the location of each cross arm should be taken.

6.7 Protection of Telescopic Joints

To prevent the ingress of soils all the telescopic joints should be protected with hemp packing or oakum held in place by hessian wired on the pipes, taking care that the telescopic movement of the pipes is not prevented.

6.8 Completion of an Installation

As the installation nears the outer surface of the dam-embankment, the operations given in 6.8.1 to 6.8.3 should be done.

6.8.1 Lengths of 50 mm spacer pipe should be assembled to extend the installation progressively to the surface of the completed embankment.

6.8.2 As construction progresses pipe cover should be removed, assembled 50 mm spacer pipe extension should be installed and the soil (rock-free or rocky) backfilled or mounded around the pipe as the case may be, to outer embankment slope.

6.8.3 Concrete should be placed near the top of the slope as shown in Fig. 1.

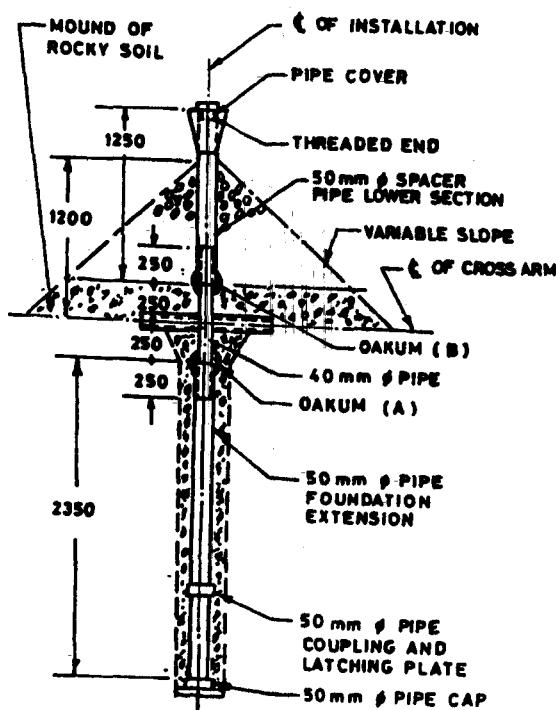
7 OBSERVATIONS

7.1 The equipment required for obtaining settlement readings included the torpedo (Fig. 3). The elevation of the cross arm units are determined by lowering the torpedo through the reading scale (Fig. 4) and into the pipe system by means of the steel tape or calibrated/aircraft cable. Pawls on the torpedo successively engage the lower ends of the 40 mm pipe (measuring points on each cross arm unit) and upon reaching the bottom of the installation they latch in a closed position to enable the torpedo to

be withdrawn from the system. When readings are taken, the reading scale is attached to the top section of the pipe projecting from the existing installation. The elevation of the levelling plate on top of the reading scale should be established from a permanent benchmark of the dam. Vertical distances from the top of the reading scale to the respective cross arm measuring points are obtained by using the torpedo and attached cable.

7.2 Determining Original Elevation

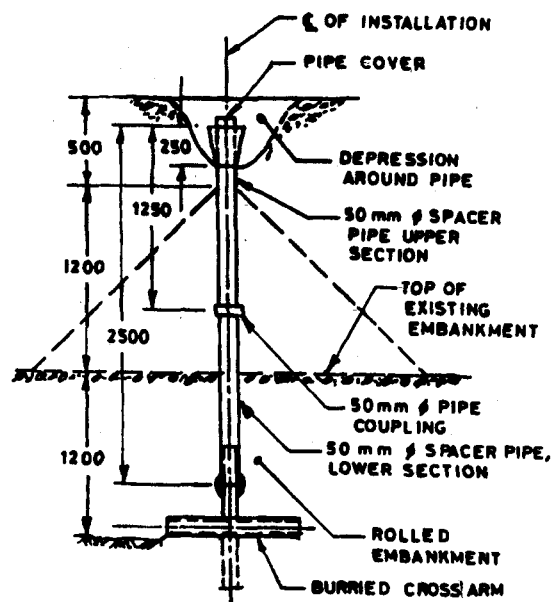
7.2.1 The original elevation of each cross arm should



PHASE 1

Operations

1. Locate centre of installation
2. Level 75 cm area adjacent to centre of installation
3. Bore 100 mm dia hole; clean hole
4. Place and align foundation extension in hole
5. With a tremie, place sand - cement grout around extension pipe
6. Place and align cross arm unit
7. Place oakum and wrap with burlap at (A), backfill to 225 mm above centre line of cross arm
8. Obtain original elevation of cross arm measuring point
9. Place and align lower section of spacer pipe
10. Place oakum and wrap with burlap at (B), seat pipe cover
11. Mound soil around pipe to lower end of pipe cover



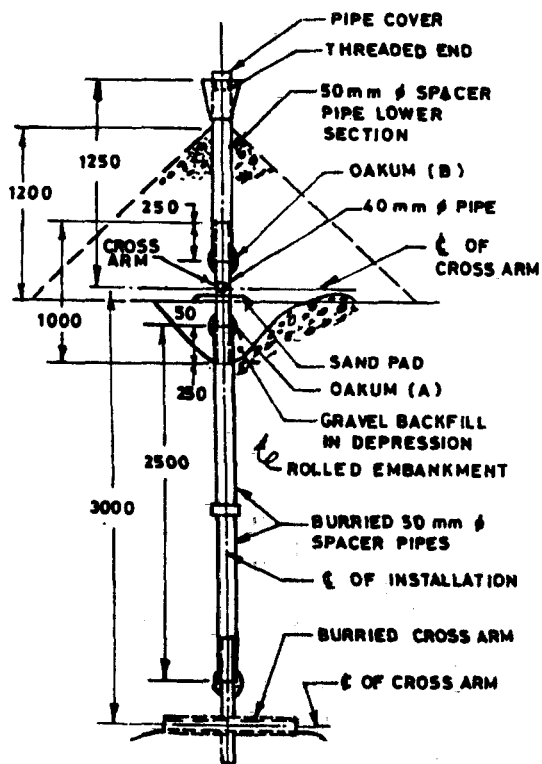
PHASE 2

Operations

1. Raise embankment 100 mm above cross arm
2. Place and align upper section of spacer pipe
3. Place pipe cover and mound around pipe
4. Continue embankment placing to 150 mm above top of pipe cover, leaving a depression around pipe

All dimensions in millimetres.

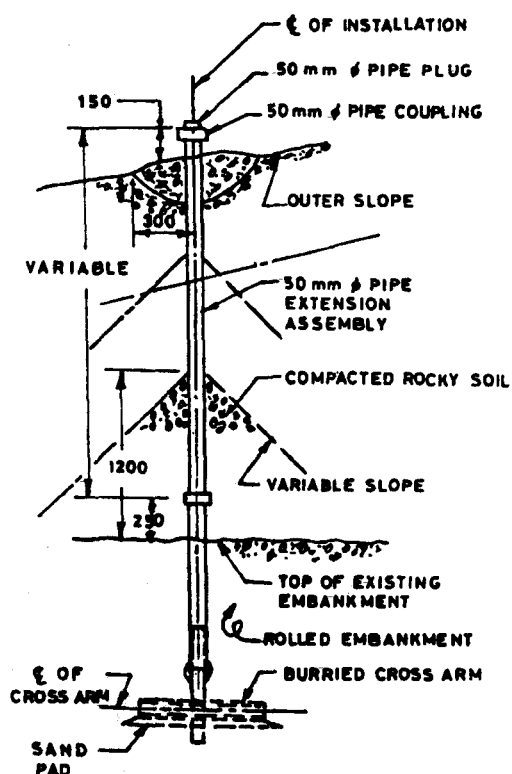
FIG. 6 TYPICAL VERTICAL MOVEMENT DEVICE — INSTALLATION IN ROCKY SOILS (Continued)



PHASE 3

Operations

1. Check centre of installation
2. If necessary, realign column
3. Place and pad
4. Place and align cross arm
5. Repeat operations 7 through 11 of Phase 1



PHASE 4

Operations

1. When embankment is raised to 300 mm below top of lower spacer pipe, remove cover, place and align pipe extension assembly
2. Place mound around pipe as embankment is raised
3. Place concrete cap

All dimensions in millimetres.

FIG. 6 TYPICAL VERTICAL MOVEMENT DEVICE — INSTALLATION IN ROCKY SOILS

be determined by levelling methods with reference to an established benchmark located away from the dam. The original elevation should be recorded when a cross arm is installed. These original elevations should be recorded when backfill around a cross arm is placed to within approximately 500 mm of the top of the 40 mm pipe. At that time, the pipe cover should be removed, the reading scale attached and the elevation of the zero or reference point on the scale determined to the nearest 2 mm. Then the torpedo (which is attached to an Engineer's tape or calibrated aircraft cable) should be lowered into the pipe and the initial distance to the measuring point of the top cross arm unit read and recorded. The distance should be read and the elevations of all cross arm measuring points below the cross arm unit just placed determined. After determining the elevation of the bottom cross arm in the system, the torpedo should be dropped to the latching place to latch the pawls (see Note).

The torpedo should then be withdrawn from the pipe column.

NOTE — If the pawls on the torpedo fail to latch when the device reaches the bottom of the pipe column, a section of 10 mm pipe 60 mm long may be slipped over the tape cable and lowered by means of a wire into the installation until it rests on top of the torpedo. This added weight should latch the torpedo.

7.3 Current elevations of cross arm measuring points should then be determined by using the established elevation of the top of the reading scale and the measured vertical distance. Then by subtracting the current elevations of originally established (see 7.2) vertical movements of cross arms should be obtained. Elevation of the top of the reading scale should be obtained for each set of periodic readings with reference to a permanent benchmark but this elevation is temporary and is not a fixed point on the structure.

7.3.1 Water depth in the pipe system should be determined by using the water level indicator, every time the set of observations by torpedo is taken.

7.4 A complete set of readings should be made on the entire existing installation, each time an additional cross arm unit is installed during construction of the embankment. When construction is suspended the system should be so adopted so that readings can be made at monthly (30 days) intervals or earlier in special cases, if required. The first set of periodic reading should be made immediately after installation, thereafter readings should be taken every three months for the first three years and every six months thereafter. A proforma for the record of observations is given in Annex A.

8 RECORD OF TESTS

8.1 Record tests of embankment and foundation materials at the instrument installation are necessary to obtain data on the soils adjacent to the instruments. These should include tests for grain size analysis, consistency limits and consolidation characteristics for the soil placed at every cross arm level.

8.2 In addition, at each unit of the internal vertical movement apparatus in earthfill material, two field density tests should be made; one test sample should be obtained from the soil at the bottom of the trench excavated for the cross arm unit; the other should be obtained in the tamped backfill of the trench after it has been brought up to grade.

8.3 When all or a part of the dam is founded on highly compressible materials representative undisturbed samples should be obtained from the foundation at the location of the vertical movement installations, unless suitable samples have been obtained previously from these locations.

8.4 No tests are required when the internal movement device is placed on rock foundation unless specially requested.

8.5 Tests at the internal movement units should be designated 'record rolled', 'record tamped' or 'undisturbed' depending on the material being tested.

9 PROGRESS REPORTS

9.1 The report should show the current elevation of the embankment at the installation, the number of cross arms, the compression of the embankment and the settlement of the foundation. The narrative portion of the progress report should discuss variations from the instructions and installation procedures. Photographs, drawings and charts pertinent to the installation should be included.

9.2 The report should also contain results of

record tests mentioned in 8. In addition, other relevant data, such as the corresponding lake levels, pore pressure in the vicinity of the cross arm installation rainfall on the day of observation and the exact stage of construction should also be reported.

10 GENERAL GUIDANCE

10.1 All steel parts of the installation should be coated with 2 coats of red oxide or any similar anti-corrosive paint to prevent corrosion.

10.2 The edges of the 40 mm pipe should be machine cut or filed flat so that the accuracy of the readings is maintained.

10.3 It is necessary to see that the 40 mm steel pipe is securely bolted to the channel to prevent slippage. Alternatively it could be welded.

11 MAINTENANCE

11.1 It is essential to ensure plumbness of the installation by preventing movement of heavy equipment, particularly during construction.

11.2 Capping of the installation during and after installation should be ensured to prevent any foreign debris, etc, being introduced into the installation by unauthorized personnel.

11.3 Each time the measuring torpedo is used, it should be properly cleaned and lubricated for free movement of the spring loaded pawls. The steel tape of the stainless steel cable should also be inspected for any kinks or damage and cleaned and oiled, if required.

11.4 To prevent unnecessary misuse and possible loss of the measuring torpedo, use of a dummy torpedo of equal length and 33 mm dia with soft wire or strong nylon cord or string should be used to determine if there is any inclination and/or obstruction in the installation. Thereafter the measuring torpedo should be used.

12 ADVANTAGES AND LIMITATIONS

12.1 Advantages

The installation is relatively simple and cheap which provides accurate determination of consolidation at different levels during and after construction, thereby controlling the progress of fill material. This data provides a warning of any instability in the foundation and/or embankment due to uneven settlement which may call for remedial measures.

12.2 Limitations

Since drill hole installations are not possible in this case the device has to be placed during construction of embankments. This will obstruct the movement of

construction equipment causing delay and possible damage to device.

Maintaining the vertical alignment of the whole installation is very essential for the measurement of the settlement with torpedo. Since construction of high dams take comparatively longer period, there exists greater possibility of horizontal movements in embankment and plumbness of the installation is affected. Hence cross arms may be installed with greater confidence in medium dams of 30 to 40 metres height.

SECTION 2 ELECTRICAL TYPE

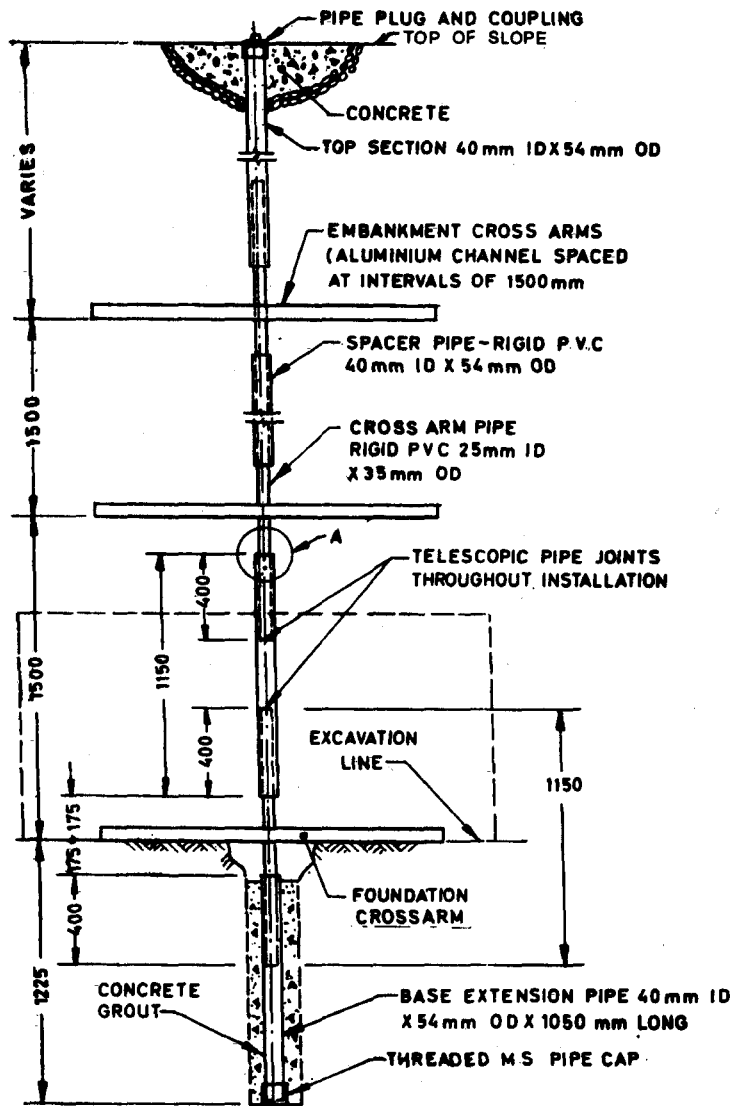
13 EQUIPMENT

13.1 The electrical type of cross arm installation is

similar to the mechanical type (Section 1) except for the following:

- Plastic pipes are used instead of steel pipes.
- Aluminium channel sections are used for the cross arms instead of steel channels.
- The aluminium channels are not fastened to the vertical pipes.
- An electrical probe attached to graduated cable is used for measuring depths of cross arm of torpedo.

13.1.1 A typical installation enabling measurements at 1 500 mm interval is illustrated in Fig. 7.



All dimensions in millimetres.

FIG. 7 TYPICAL COMPLETED CROSS ARM INSTALLATION ELECTRICAL TYPE FOR 1 500 mm SPACING OF CROSS ARMS

13.2 Components for Installation

13.2.1 Base Extension

The base pipe extension consists of a 40 mm inside diameter and 54 mm outside diameter rigid PVC pipe, 1 050 mm long, sealed at the bottom and concreted into a drill hole in the foundation.

13.2.2 Cross Arm Unit

The cross arm unit consists of a 1 000 mm long, 100 mm × 50 mm Aluminum channel with a hole in the centre through which a 1 150 mm long, 25 mm inside diameter and 35 mm outside diameter rigid PVC pipe is passed normal to the channel. The cross arm pipe should be fitted with four rubber 'O' ring seals at each end located in grooves to provide a water-tight overlap with the spacer section (see Fig. 9).

13.2.3 Spacer Section

This section is 1 150 mm long, 40 mm inside diameter and 54 mm outside diameter rigid PVC pipe that serves as a spacer between the cross arm units.

13.2.4 Top Section

The piece is a rigid PVC pipe 40 mm inside diameter and 54 mm outside diameter and of variable length extending the column of pipes to the surface of the embankment. It is capped by a suitable pipe coupling and plug. When the installation is completed, the top section should be encased in concrete to prevent horizontal displacement.

13.3 Equipment for Observation

13.3.1 Measuring Probe

The probe contains a metal proximity sensing device and an electrical transmitter. As the probe passes through the hole in the aluminum channel which is located in each section of tubing, a signal is transmitted to a receiver unit. The depth of the probe is measured when signal is heard; by the length of sealed cable in the tubing.

13.3.2 Water Level Indicator

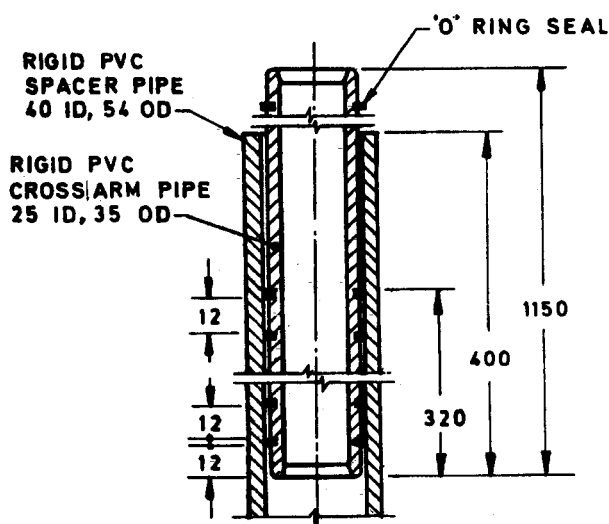
Any suitable device as described in IS 6935.

14 METHOD OF LOCATING A COLUMN OF CROSS ARMS (See 4)

15 DESCRIPTION OF INSTALLATION

The installation comprises of series of alternate telescopic 25 mm diameter and 40 mm diameter pipe section placed in the embankment along with cross arms. The base extension is installed at the foundation level while the cross arm and spacer sections are

placed alternatively as the construction proceeds. To prevent the ingress of soil, all telescopic joints shall be protected with rubber 'O' ring seals (see Fig. 8). The cross arms are installed progressively as the embankment is placed. Settlement readings are obtained by means of the specially designed measuring probe. The probe is lowered into the pipe barrel by means of a calibrated electrical cable attached to it. While making a measurement the probe is lowered into the pipe barrel by means of a calibrated electrical cable attached to it. While making a measurement the probe is lowered to a point, a few centimetres below the elevation of the uppermost cross arm, then lifted until audio signal is heard. It may be necessary to pass the probe up and down slowly at this elevation to precisely locate the position of the cross arm.



Detail at 'A' of Telescopic Pipe Joint

All dimensions in millimetres.

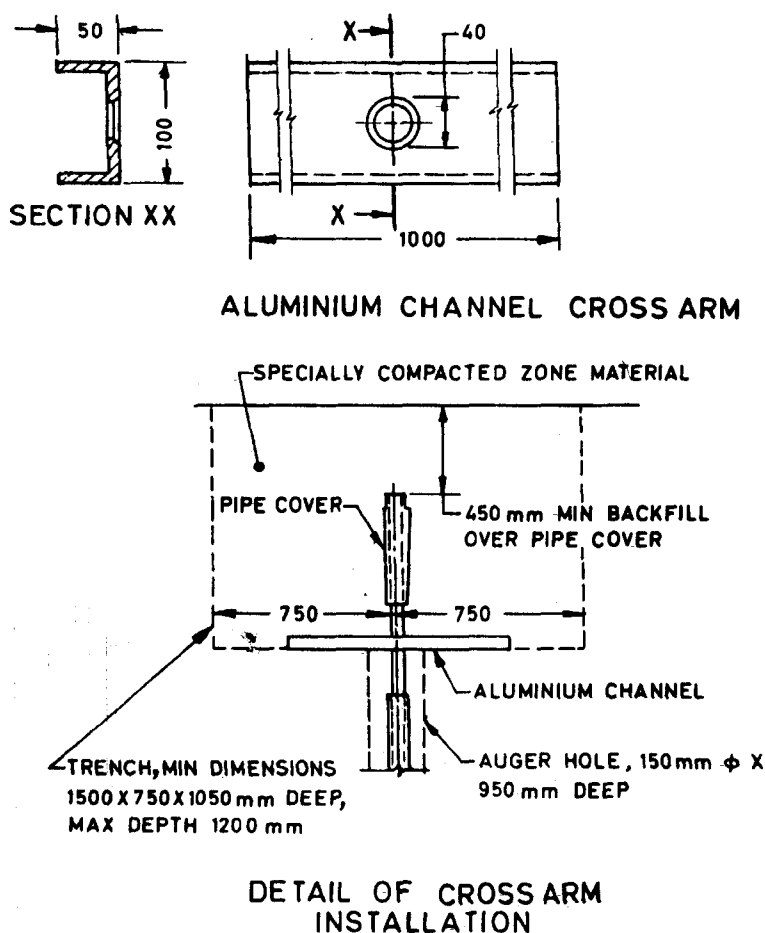
FIG. 8 TYPICAL COMPLETED CROSS ARM INSTALLATION
ELECTRICAL TYPE FOR 1 500 mm SPACING OF
CROSS ARMS

16 INSTALLATION

16.1 (See 6.1)

16.2 Base Extension

The base extension for the device consists of two pieces of pipe which form the extension into the foundation. This extension is assembled and set into a 100 mm minimum diameter hole which has been drilled to the required depth into the foundation. The hole may be drilled depending upon the type of foundation material and the equipment available. After setting the pipe extension, the backfill around the 40 mm pipe should be carried out with cement grout to within 175 mm of its top. If the foundation cross arm is not installed immediately, a temporary pipe



All dimensions in millimetres.

FIG. 9 TYPICAL COMPLETED CROSS ARM INSTALLATION ELECTRICAL TYPE FOR 1 500 mm SPACING OF CROSS ARMS

cover should be placed over the extending 40 mm pipe and covered with a 450 mm minimum of compacted embankment material.

16.3 Placing Cross Arm Units

The vertical movement apparatus (see Fig. 7) can be installed either in 'rock-free' soil or in 'rocky' soils, or in a combination of soils as found in a zoned type of earth and rockfill embankment. A 'rock-free' soil is defined as a soil that can be penetrated by; 250 mm diameter power auger. Installation of the apparatus in 'rock-free' soils is given in 6.3.1 and in 'rocky' soils in 6.3.2.

16.3.1 Procedure for Installation in Rock-Free Soils

16.3.1.1 In 'rock-free' soils the embankment should reach an elevation of approximately 4 500 mm above the measuring points of a cross arm unit previously placed before excavating the trench and boring the hole for the cross arm. After excavating the trench and boring the hole of a cross arm unit, a section of light-weight pipe or tubing may be placed in the hole

to keep dirt from entering the pipe system when the pipe cover is removed from the existing installation. The pipe cover should be removed and replaced as required with a twisting motion in order not to disturb the packing between the lengths of telescoping pipe.

16.3.1.2 A practical method for boring the required holes below the excavated trench for a cross arm unit is by the use of a power auger. After the cross arm unit is installed, the angular space surrounding the pipe in the bore should be backfilled with selected fine material and the soil compact day hand rodding around the telescoping pipe section.

16.3.1.3 When the embankment contains a considerable amount of rock, the augering of holes for installation of cross arm units can be expedited if the backfill over the pipe cover is of selected fine material. This fine material can be placed and compacted inside a cylinder of metal pipe or tubing having an internal diameter of approximately 250 mm. The pipe may be progressively jacked to a higher elevation. When the hole is augered for succeeding cross arm unit, most of the fine material is removed.

16.3.1.4 *Backfilling trenches for cross arm unit*

When the trench has been backfilled with typical embankment materials to within approximately 300 mm of the top of the 25 mm pipe (bottom of pipe cover) the initial elevation of the cross arm measuring point should be recorded as described in 17.2. Thereafter, a minimum of 500 mm of typical embankment material should be compacted over the pipe cover before embankment placing operations are resumed at the place of installation.

16.3.2 *Procedure for Installation in Rocky Soils*

16.3.2.1 Since boring of holes for aligning the cross arm device is not possible in rocky soils, a practicable method is mounding around the 25 mm pipe of the cross arm device. This method should be adopted in perviously zoned embankments.

16.3.2.2 The cross arm device should be placed and then aligned and backfilled with pervious (rocky) material up to 175 mm above the cross arm. The 40 mm spacer pipe should then be placed and aligned.

16.3.2.3 Rocky material should be mounded around the upper section of spacer pipe. Embankment placing should be continued to 75 mm above the top of pipe cover leaving a depression around it. A 50 mm thick sand pad should be placed and then the cross arm device should be placed and aligned (after removing the top cover of the upper spacer pipe).

16.4 *Correction for Alignment*

After installing the 1 150 mm length of spacer pipe in the bored hole and also the cross arm assembly, the protective pipe cover should be removed and the vertical alignment of the system checked by lowering a plumb bob from the straddle hub strings. It is impracticable to correct the error, succeeding pipe sections should be placed vertically and the offset from the true vertical alignment recorded. If a deviation from vertical alignment is found, an attempt should be made immediately to correct the error.

16.5 *Rotation of Cross Arms*

Each cross arm section should be placed in proper alignment of the vertical column of pipe. When each new cross arm unit is installed, the channel section of the new unit should be rotated 90° (clockwise) with respect to the channel section previously placed.

16.6 *Compaction of Soil Around Installation*

Soil around the installation should be compacted to the equivalent unit dry weight of the surrounding material and record of samples of the soil at the location

of each cross arm should be taken.

16.7 *Protection of Telescoping Joints*

To prevent the ingress of soil, all the telescopic joints shall be protected with rubber 'O' ring seals as described in Fig. 8.

16.8 *Completion of an Installation*

As the installation nears the outer surface of the dam embankment, the operations given in 16.8.3 should be carried out.

16.8.1 Lengths of 40 mm spacer pipe should be assembled to extend the installation progressively to the surface of the completed embankment.

16.8.2 As construction progresses pipe cover should be removed, assembled, 40 mm spacer pipe extension should be installed and the soil (rock-free or rocky) backfilled or mounded around the pipe as the case may be, to outer embankment slope.

16.8.3 Concrete should be placed about the top of the slope as shown in Fig. 7.

17 *OBSERVATIONS*

17.1 The equipment required for obtaining settlement readings are an Electrical Probe, Marked Cable and an Indicator. The elevation of the cross arm units are determined by lowering the probe through the reading scale (see Fig. 10) and into the pipe system by means of the calibrated cable. The cable is passed over the pulley and the probe is lowered into the 25 mm pipe (measuring points on each cross arm unit). On reading the location of each cross arm, the indicator gives an audio signal upon which the reading is taken with the help of the marking on the cable and on the scale. When readings are made, the reading scale is attached to the top section of the pipe projecting from the existing installation. The elevation of the levelling plate on top of the reading scale should be established from the top of the reading scale to the respective cross arm measuring points are obtained by using the probe and attached cable.

17.2 The original elevation of each cross arm should be determined by levelling methods with reference to an established benchmark located away from the dam. The original elevation should be recorded when a cross arm is installed and backfill around it is placed to within approximately 300 mm of the top of the 25 mm pipe. At that time, the pipe cover should be removed, the reading scale attached, and the elevation of the zero or reference point on the scale determined to nearest 2 mm. Then the probe (which

is attached to a calibrated electrical cable) should be lowered into the pipe and the initial distance to the location of the top cross arm unit read and recorded. This distance should be read and the elevations of all cross arm measuring points below the cross arm unit just placed determined. After determining the elevation of the bottom cross arm in the system, the probe should be withdrawn from the pipe column.

17.3 See 7.3.

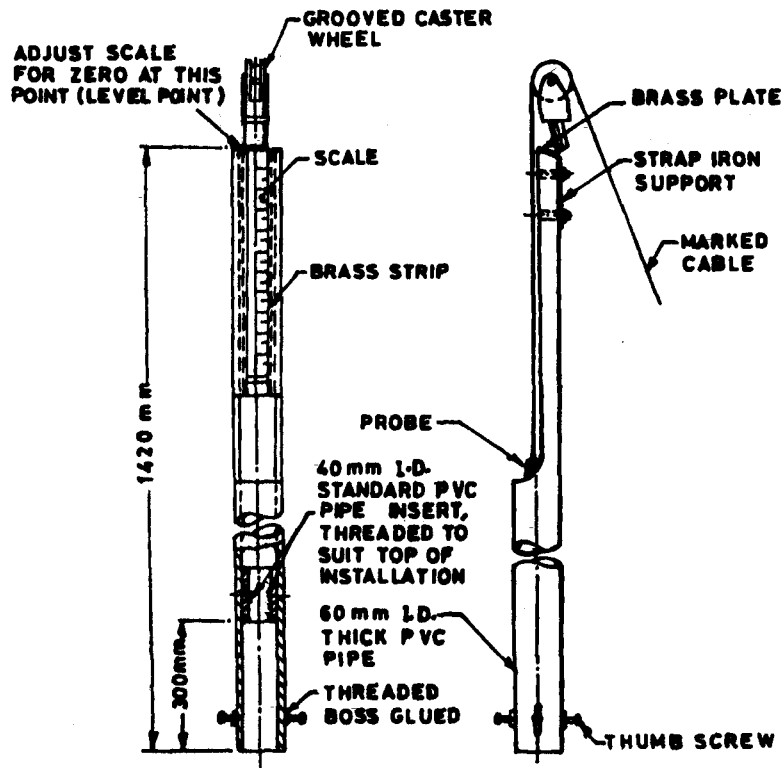
17.3.1 See 7.3.1.

17.4 A complete set of readings should be made on the entire existing installation each time an additional

cross arm unit is installed during construction of the embankment. When construction is suspended, the system should be adopted so that readings can be taken at monthly (30 days) intervals or earlier in special cases, if required. The first set of periodic readings should be taken immediately after installation, thereafter readings should be taken every three months for the first three years and every six months thereafter. A proforma for the record of observations is given in Annex A.

18 RECORD OF TESTS (See 8)

19 PROGRESS REPORTS (See 9)



NOTE — Use device as shown during construction. Thereafter cut device to 1 120 mm length to fit top of installation.

FIG. 10 READING SCALE WITH ADAPTOR

ANNEX A
(*Clauses 7.4 and 17.4*)

PROFORMA FOR RECORD OBSERVATION OF VERTICAL CROSSARM INSTALLATION

Project.....
Location.....
Date.....
Observed by.....

Dam.....
Top of dam.....
Reservoir water level R. L.....
Water level in the installation.....

Cross arm No.	Top Level of Measuring Scale	Tape Reading	Correction for Torpedo Length	Corrected Scale Reading	Original Elevation of Cross Arm (See Notes 1 and 3)	Present Elevation of Cross Arm (See Note 1)	Settlement of Cross Arm	Original Distance Between Cross Arms (See Notes 2 and 3)	Present Distance Between Cross Arms	Consolidation Between Cross Arms	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)

NOTES

- 1 The elevation of the cross arms are the elevation of the cross arm measuring points.
- 2 Original distance between cross arms is the difference between elevations of successive cross arm measuring points the cross arm unit is placed.
- 3 Once established, the original elevations of cross arm measuring points and the original distance between points are fixed values and appear as constants in later readings.

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